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Physical modeling of rainfall induced landslides

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Early warning systems for shallow landslides typically use real-time measurements and forecasts of rainfall, and empirical correlations between past landslide occurrence and rainfall patterns. Often, these relationships describe whether certain combinations of rainfall and pre-existing groundwater levels are of elevated risk of landslide triggering. However, not all combinations of rainfall and pre-existing groundwater levels lead to landslide events necessarily having the same consequences in terms of landslide mobility (velocity and distal reach of the landslide). Using the technique of geotechnical centrifuge modeling, five physical models of a loose granular slope were brought to failure under varying antecedent rainfall conditions to evaluate the consequences of the triggered landslide. The physical models were constructed to replicate a shallow, thirty degree slope of loose granular material, including a significant base length. Using a high speed camera at a frame rate of 1000 frames per second, the landslide event for each test was captured in its entirety in video and images. These images where then used to calculate the mobility of the landslide using Particle Image Velocimetry techniques.

The five physical models tested under their respective antecedent rainfall conditions triggered landslide events that were all initially small localized failures at the toe of the slope. In the test scenarios where low antecedent rainfall conditions were present, the localized failure did not progress and the mobility of the landslide was small. For scenarios where the antecedent rainfall conditions were high, the initial small localized failure acted as the monotonic trigger to shear the loose contractile saturated sand at the base of the slope, causing liquefaction to occur in the base region. The phenomena of static liquefaction in these tests was captured in the high-speed images, where it showed the evolution from localized failure to base liquefaction. As the base experienced liquefaction in these models, it essentially removed all of the support it provided to the sloped portion of the model. This resulted in the slope traveling further and at greater velocities than it otherwise would have at that particular antecedent rainfall conditions. It was found that liquefaction of the base not only caused a greater distal reach and velocity when compared to the low antecedent rainfall models, but the total volume of the landslides was also significantly higher. The high mobility and total volume of these landslides highlight the important role antecedent rainfall conditions have on the consequences of a landslide. These findings further indicate the importance of including antecedent rainfall levels when developing an early warning systems.